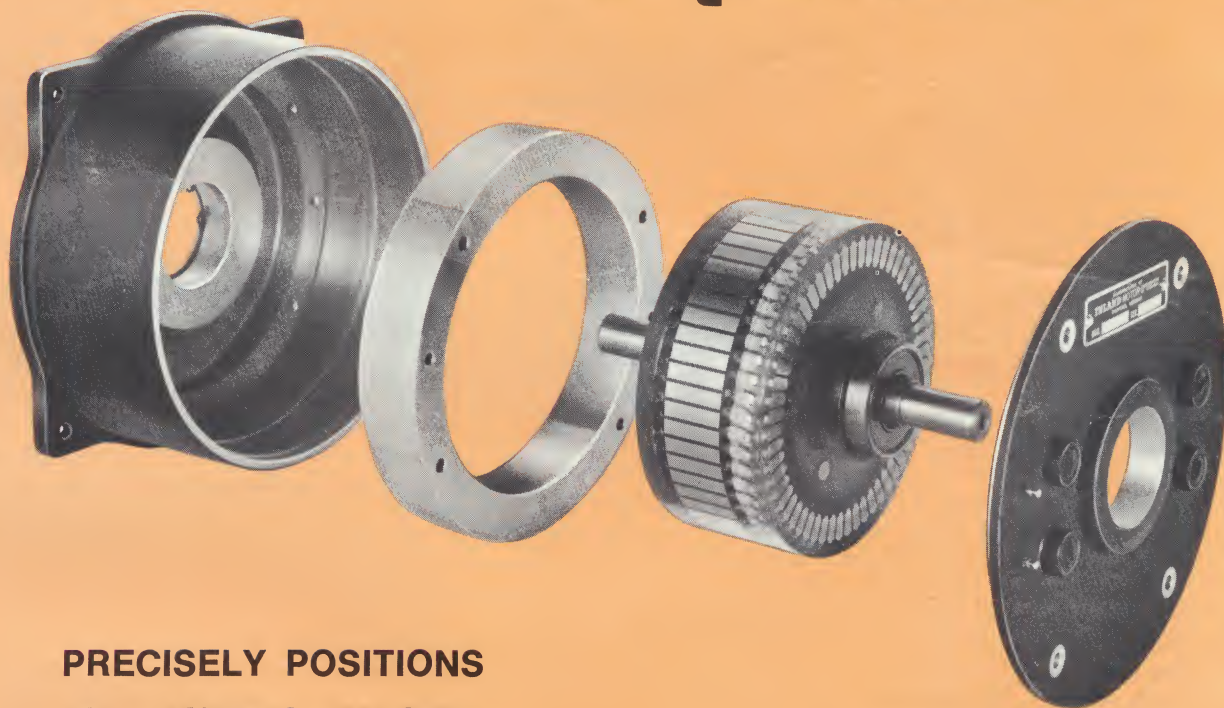




torqy talks

INLAND MOTOR CORPORATION • RADFORD, VIRGINIA

INLAND dc DIRECT-DRIVE TORQUE MOTOR



PRECISELY POSITIONS
ALL TUNING STAGES
IN AUTOMATICALLY TUNED
LINEAR POWER AMPLIFIERS



INLAND MOTOR

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INLAND DC DIRECT-DRIVE TORQUE MOTORS FOR PRECISE POSITIONING...

SYSTEM CONFIGURATION

In any design that contains automatic tuning, especially in automatically tuned linear power amplifiers, the most critical areas are in the design of the mechanical tuning mechanism. The main problems arise in reliability due to the complexity in the mechanical linkage and gearing usually associated with this type of device. Gates Radio Company made an extensive evaluation to try to get around this problem in a new design of a linear power amplifier. Gates solved their problem by using Inland direct-drive torque motors as the drive source. This particular linear power amplifier, see simplified block diagram Figure 1, was designed for operation in high performance transportable or fixed station SSB transmitting systems.

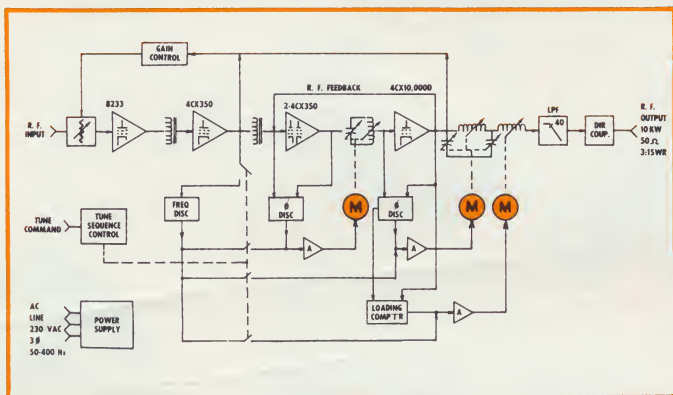


Figure 1.

AMPLIFIER DESIGN

The Amplifier requires only 0.1 watt of RF drive power to automatically tune from 2-30 MHz in 25 seconds or less. To obtain this response time, a reliable simplified tune sequence was required to govern the automatic tuning circuit with a minimum of control information from this exciter. Free positioning of the tuned elements is achieved directly from information taken from the input RF frequency, making the power amplifier suitable for use with any exciter capable of delivering 100 milliwatts of drive power. To overcome the reliability problem associated with this type of equipment, it was desirable that the number of servo systems be minimized and, therefore, in this design only three servo systems were used. The input stage is broadbanded and, therefore, only a driver output tuning stage, a final output tuning stage and final loading tuning stage are required.

DC TORQUE MOTOR SERVO SYSTEMS

On these three stages mechanical linkages and gearing were eliminated by the use of direct-drive DC torque motors. The Inland DC torque motor responds to the voltage and current applied, therefore, a broad band of speed ranges is possible without the use of multiple gear trains. Another desirable feature of this power amplifier was modular construction. By putting all the low level RF circuitry in a removable module, accessibility and ease of maintenance was accomplished. Since linkages, gear boxes, etc. were eliminated,

weight was reduced and other complications in maintenance were overcome. Modular construction permits continued use of the amplifier in a manual mode, thus reducing down time when service is required on the low level RF circuitry. Automatic frequency change is accomplished through a sequential control which is activated by a specific tune command and a new reference frequency. The three Inland DC servo motors, operated in closed loop proportional control, accomplish this adjustment.

With high response time and the elimination of mechanical linkages tuning can nominally be accomplished in a 10 second broadswing from one extreme to the other, precise tuning generally can be accomplished in less than 25 seconds. Through the use of specially developed electronics, the change in frequency is sensed by a frequency discriminator which coupled through the output of this section of a broadband amplifier develops an analog signal to provide coarse positioning of the tuning and loading component. The driver and final outputs are sampled by a phase detector and compared with their input signals for precise determination of resonance. This provides the error signal to the operational amplifiers which cause the DC torque motors to adjust the plate tank circuit of the driver and final output stages to their proper frequency position.

The final amplifier loading is controlled by sensing the voltage gain of the output stage. Here the signal again drives a DC torque motor similar to the fine and coarse tuning adjustments of the plate tank circuit.

The motors are directly coupled to the shaft, hence, there is no dead zone caused by gear backlash or other mechanical linkages. Rapid response and good system stability is accomplished because of the high torque to inertia ratios of the motors. By the use of direct-drive, little stored energy is built up in the rotors of these units. Their speed is readily controlled directly proportional to the applied voltage and the torque is controlled by the amount of current flow through the units. Hence, in a closed servo loop these motors can be brought to position and stopped instantaneously, thus eliminating the need for slip clutches.

In as much as the amplifier is completely signal seeking, it will respond to inputs from any LSB exciter having 100 milli-watts or more of drive power and will send a signal to the operational amplifiers driving the motors. Hence, a large error signal will cause the motors to be driven hard to their desired position. As they approach this position and the error signal decreases, the power applied to the motor is reduced and the response of the motor follows very closely this reduction in input, such that, when the unit reaches its desired position the motor comes to rest without overshoot.

Also, as mentioned earlier, if an RF modular drawer is removed and manual operation is desired, motor control switches can be used. The high damping inherent in these motors cause rapid stopping, thus maximum continuity in service during equipment emergencies can be accomplished even though automatic control has been removed.

MOTOR SELECTION

In this particular application an Inland DC direct-drive motor type T4054 was selected to be used in all three tuning circuits. Direct-drive servo motors are particularly suited for servo systems where size, weight, power requirements and response times must be minimized and where high position and rate accuracies are desirable. Torque motors have these important advantages over other servo system actuators:

- High torque-to-inertia ratio at the load shaft: a direct-drive motor provides the highest practical torque-to-inertia ratio where it counts — at the load shaft. Since it is directly coupled to the load, it has no gear train. A high ratio at the other end of a large gear train becomes sluggishly small when computed at the load shaft. A gear train decreases the torque-to-inertia ratio by a multiple equal to the gear train ratio, resulting in poor acceleration capability.
- High coupling stiffness: the direct-drive torque motor is attached directly to the load itself — therefore no gears, no backlash errors. High coupling stiffness (and, therefore, high mechanical resonance frequency) results in high servo stiffness.
- Fast response: torque motors respond rapidly at all operating speeds because the rate at which armature current rises, and torque is developed, is accelerated by exceptionally low self-inductance. Special features, such as high-level magnetic saturation of the armature core together with the use of a large number of magnetic poles, reduce the armature self-inductance to very low values. The resulting high speed with which torque is developed, after voltage is applied, is an important aid to servo stiffness.
- High resolution: the direct-drive use of torque motors allows them to position a shaft more precisely than with gear trains. With gearing, the backlash contributes to a "dead zone" which falls in the region of the system null point, thus reducing positional accuracy. With the direct-drive system, however, the positional accuracy is practically limited only by the error detecting transducer system.
- High linearity: torque increases directly with input current, independent of speed or angular position. Electromagnetic torque is linear through zero excitation, therefore, assures no dead band.

- Compact adaptable design: the frameless torque motors are designed-in as an integral part of equipment, thus saving weight and space of the conventional motor frame or housing. In addition, the "pancake" type of construction has a form factor which is better for many applications, particularly where direct-drive is concerned. These motors can be fitted into a minimum spacing around or on the end of the shaft to be driven.
- Reliability and long life: the basic simplicity and absolute minimum of moving parts make a torque motor inherently reliable. Extensive design and production experience have put Inland torque motors in most major defense programs of the last 15 years. These include widely ranging applications under all conditions and environments from thousands of feet underwater to years of unattended operation in outer space.

MOTOR PARAMETERS

Inland's standard model T4054, shown in Figure 2, was evaluated and found to surpass all requirements of this application. Table 1 lists the characteristics for the T4054 torque motor.

TABLE 1 — TORQUE MOTOR T4054 CHARACTERISTICS

CHARACTERISTICS	MODEL	
	A	B
Peak torque (stall) lb.-ft.	2.7	2.7
Power at peak torque watts	147	147
Viscous damping lb.-ft./rad./sec. Zero impedance source	0.067	0.067
Infinite impedance source	0.0015	0.0015
Total friction lb.-ft.	0.052	0.052
Ripple torque average to peak %	5	5
Temperature rise per watt ultimate °C	1.3	1.3
Maximum permissible winding temperature °C	105	105
Mechanical time constant seconds	0.016	0.016
Electrical time constant seconds	0.002	0.002
Rotor inertia lb.-ft.-sec. ²	0.0011	0.0011
Weight lb.	4	4
Volts at peak torque	30	14.6
Amps. at peak torque	4.92	10.0
Sensitivity lb.-ft./amp.	0.55	0.27
Back EMF volts/rad./sec.	0.745	0.36
DC resistance ohms	6.1	1.46
Inductance henries	0.012	0.003

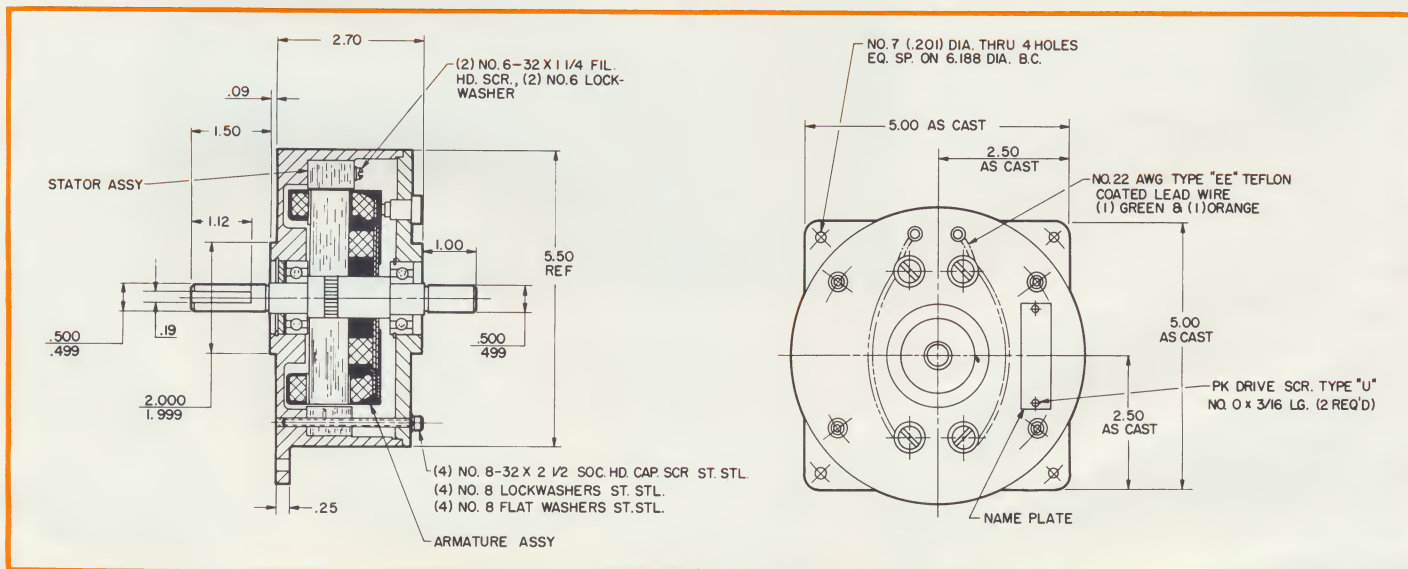
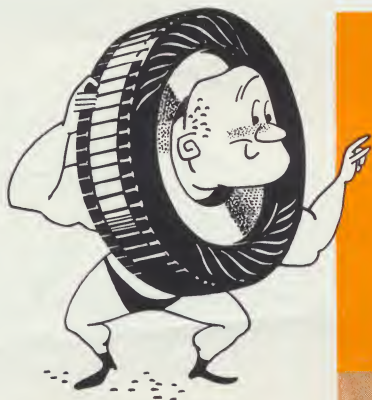


Figure 2.



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TORQY SAYS:

Inland has compiled the most complete source of information available on how to use dc direct-drive torque motors and tachometer generators in servo systems. If you want the "whole" picture ask Inland. A complete "Direct-Drive Servo Design Handbook" is available, when requested on your company letterhead. For unique applications or special problems, Inland's team of design engineers can be a big help. Contact your local representative or the factory direct.

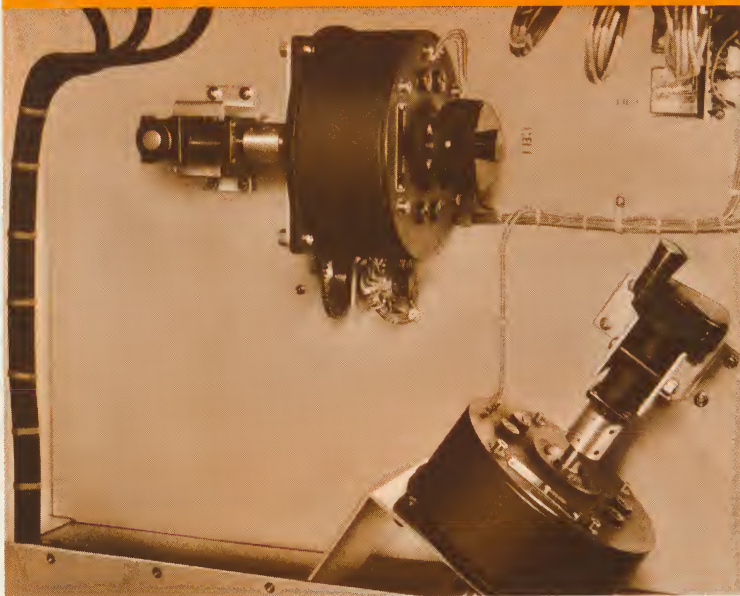


PHOTO COURTESY GATES RADIO COMPANY

Inland Motor Corporation T-4054 high torque DC servo motors directly coupled to PA circuits in the Gates ATL-10 automatically tuned linear power amplifier.

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